

Global characteristics of pion showers in the CALICE Fe-AHCAL: comparisons of data with simulations using **FTFP_BERT** physics list from Geant4 version 9.6 and version 10.1

The CALICE Collaboration ¹

Abstract

The addendum contains a comparison of the global characteristics of pion showers in the CALICE Fe-AHCAL with simulations using the **FTFP_BERT** physics list from **GEANT4** version 10.1 and version 9.6. The description of calorimeter response and longitudinal behaviour are very similar in both versions, while the predictions of energy resolution and radial shower shape are far from data in the version 9.6 compared to version 10.1.

This note contains preliminary CALICE results, and is for the use of members of the CALICE Collaboration and others to whom permission has been given.

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1 Introduction

The detailed description of the observables, event selection procedure and simulations are described in detail in CAN-040 for global observables and in CAN-048 for profile ratios. The data points and simulations with GEANT4 version 9.6p01 shown in the plots are from the paper², which superseded CAN-040. The simulations using the FTFP_BERT physics list from both GEANT4 version 9.6p01 and version 10.1 were done in the official Mokka environment (Mokka version 08.01) and were followed by the official CALICE digitisation chain from `calice_soft` version v04-08.

2 Calorimeter response and energy resolution

The reconstructed energy distributions obtained from data and simulations are shown in figure 1 for pions with initial energy 80 GeV. Figure 2 shows the response of the CALICE Fe-AHCAL to pions. The predictions from both versions are in very good agreement with each other, the overestimation of data increases with energy but does not exceed 4% up to 80 GeV. At the same time, the overestimation of the fluctuations of energy deposition becomes more significant in the version 10.1 compared to version 9.6 as follows from figure 3(left). The increased overestimation of the width of energy distributions results in the worse predictions of the relative resolutions from 30 GeV and above shown in figure 3(right). It should be noted that the good agreement between data and simulations for both calorimeter response and energy resolution is observed at 10 and 15 GeV.

²CALICE collaboration, B. Bilki *et al.*, *Pion and proton showers in the CALICE scintillator-steel analogue hadron calorimeter*, *JINST* **10** (2015) P04014 arXiv:1412.2653.

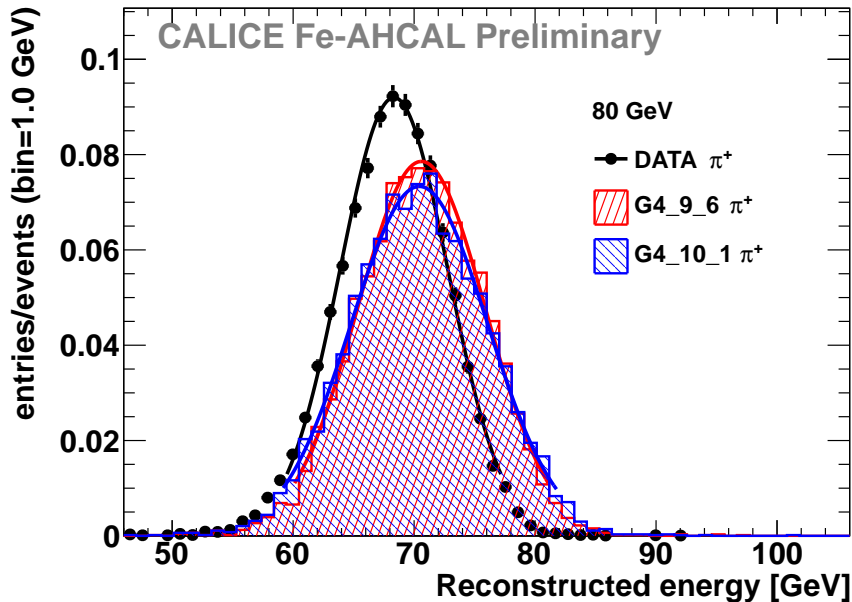


Figure 1: Reconstructed energy distribution for pions with initial energy 80 GeV for data (black circles) and simulations with GEANT4 version 9.6 (red squares) and version 10.1 (blue triangles) for FTFP_BERT physics list.

3 Longitudinal shower shape

The longitudinal shape of pion showers is well reproduced by simulations for both version 9.6 and version 10.1. The energy dependence of the mean longitudinal centre of gravity shown in figure 4 is in good agreement between data and simulations. The mean dispersion of longitudinal centre of gravity is reproduced with an accuracy of 1% in the all energy range studied by the version 9.6 and is underestimated in the version 10.1 for energies from 30 GeV and above (up to 4%) as follows from figure 5. The longitudinal shower profiles are presented in 6, where the differences between two versions are within uncertainties.

4 Radial shower shape

The observables, which characterise the radial shower behaviour, are shown in figures 7 (mean shower radius) and 8 (mean radial dispersion). Both the mean shower radius and mean radial dispersion are underestimated in the version 9.6 by $\sim 4\text{-}7\%$ and $\sim 1\text{-}3\%$ respectively. The underestimation increases in the version 10.1 up to $\sim 12\%$ for the mean shower radius and up to $\sim 5\%$ for the mean radial dispersion. The fact that pion showers become narrower in the version 10.1 compared to the version 9.6 and far from data can be also seen in the simulation to data ratios of the radial shower profiles shown in figure 9. It should be noted that the discrepancy between two versions is larger at 30 GeV than

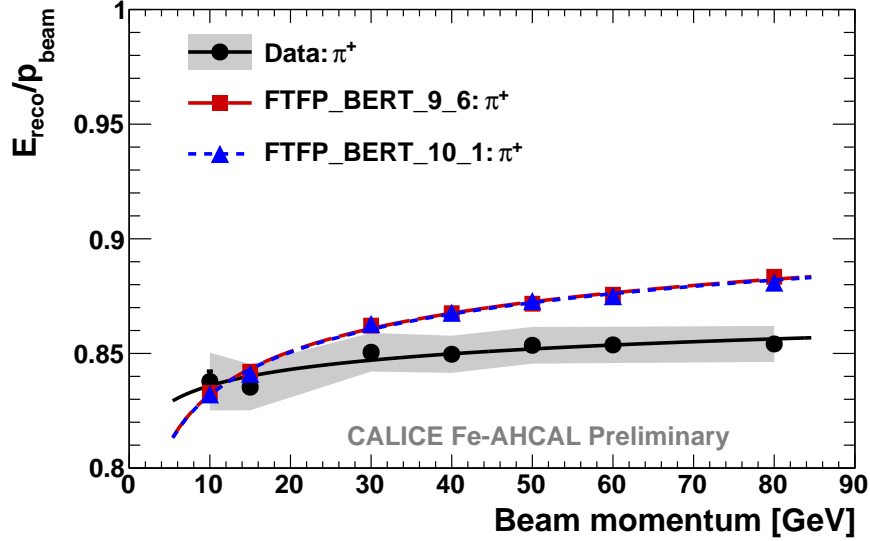


Figure 2: Calorimeter response to pions for data (black circles) and simulations with GEANT4 version 9.6 (red squares) and version 10.1 (blue triangles) for FTFP_BERT physics list. Systematic uncertainties for data are shown with grey band.

at 80 GeV.

5 Conclusion

The characteristics of showers induced by pions in the energy range from 10 to 80 GeV in the CALICE Fe-AHCAL were compared between data and simulations using the FTFP_BERT physics list from GEANT4 version 9.6p01 and version 10.1. The prediction of calorimeter response and longitudinal shower shape is similar for both versions studied. At the same time the description of the fluctuations of energy deposition and radial behaviour was observed to worsen in the version 10.1 compared to version 9.6.

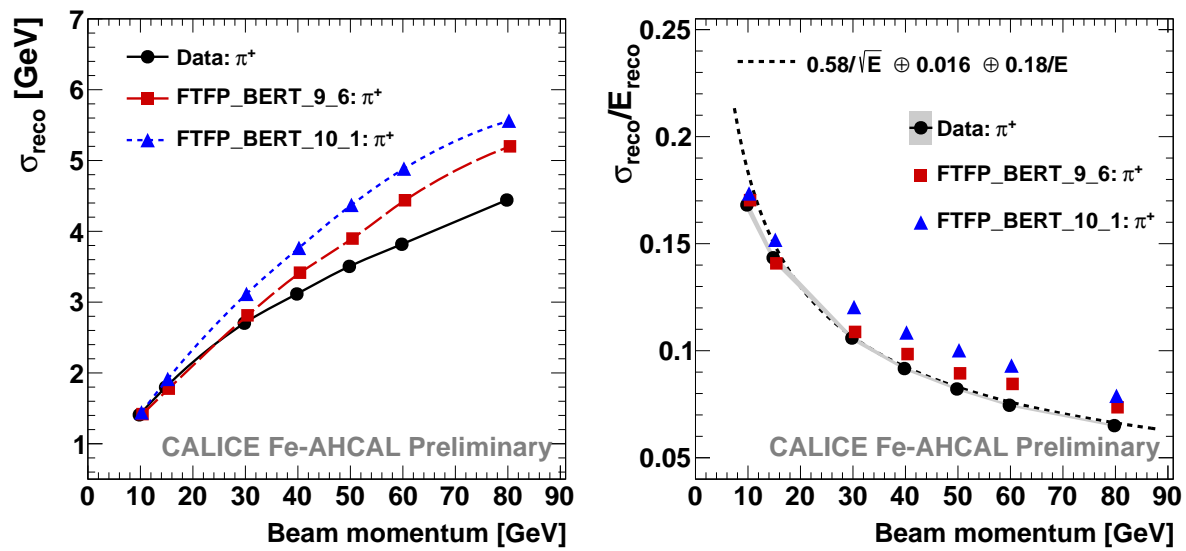


Figure 3: Absolute (left) and relative (right) energy resolution for pion showers from data (black circles) and simulations with GEANT4 version 9.6 (red squares) and version 10.1 (blue triangles) for FTFP_BERT physics list. Systematic uncertainties for data are shown with grey band.

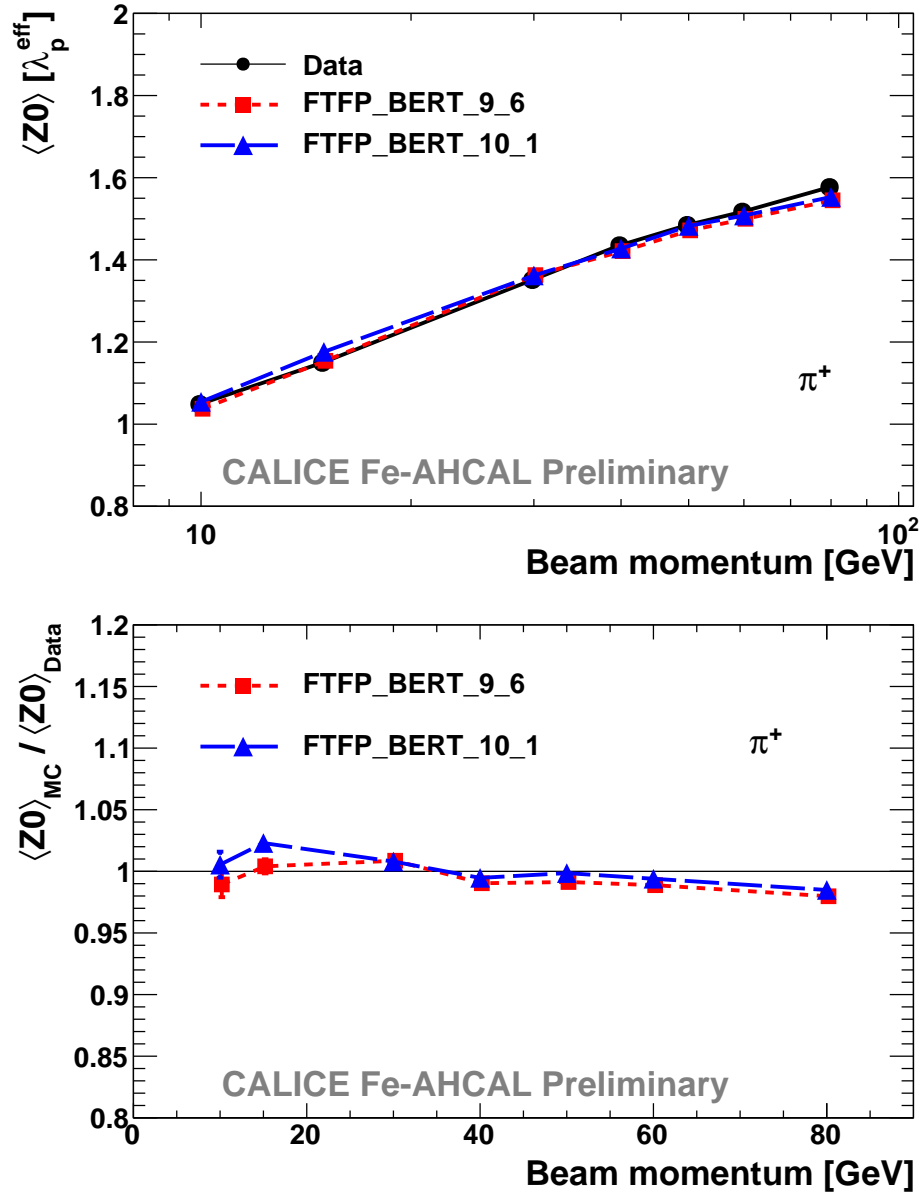


Figure 4: Mean longitudinal centre of gravity of pion shower (upper plot) extracted from data (black circles) and simulations with GEANT4 version 9.6 (red squares) and version 10.1 (blue triangles) for FTFP_BERT physics list. Ratio of simulations to data is shown in the bottom plot.

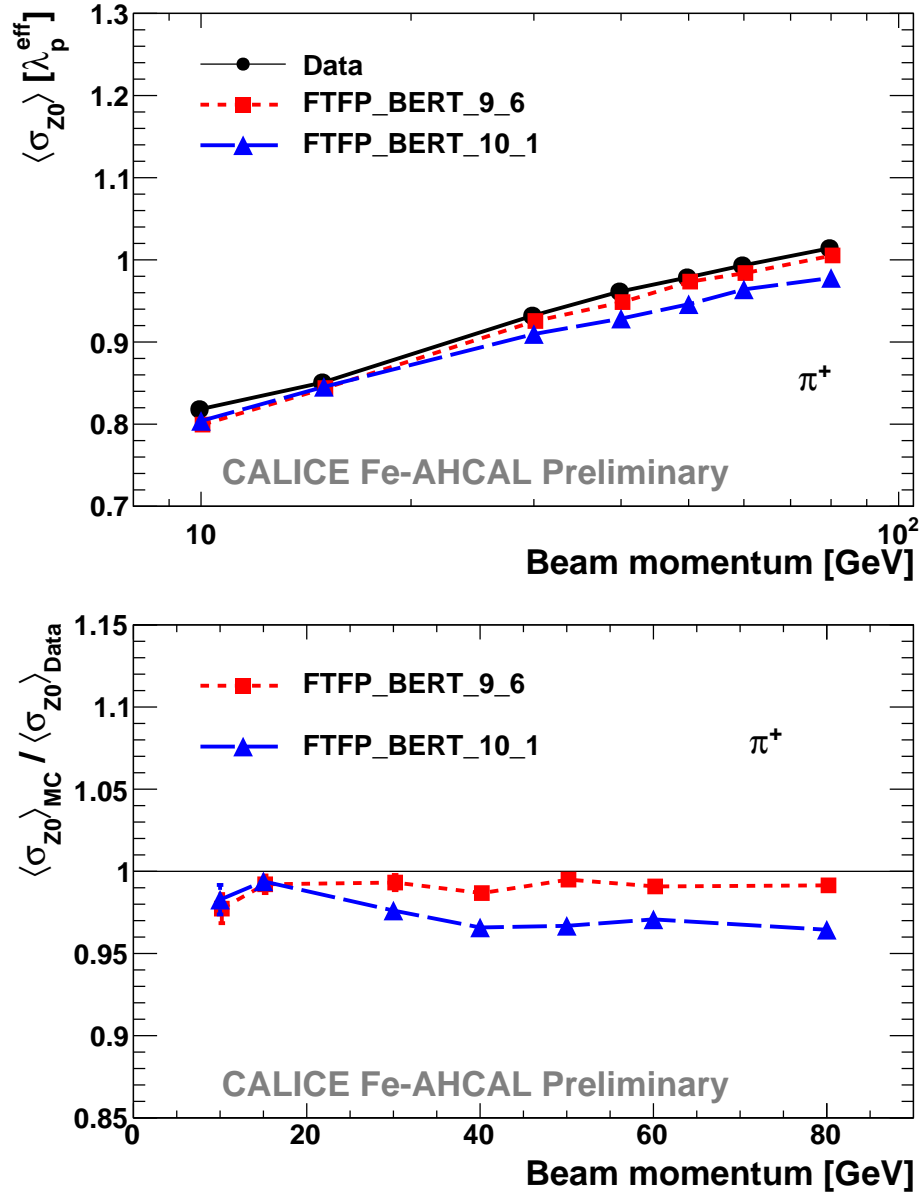


Figure 5: Mean standard deviation of longitudinal centre of gravity of pion shower (upper plot) extracted from data (black circles) and simulations with GEANT4 version 9.6 (red squares) and version 10.1 (blue triangles) for FTFP_BERT physics list. Ratio of simulations to data is shown in the bottom plot.

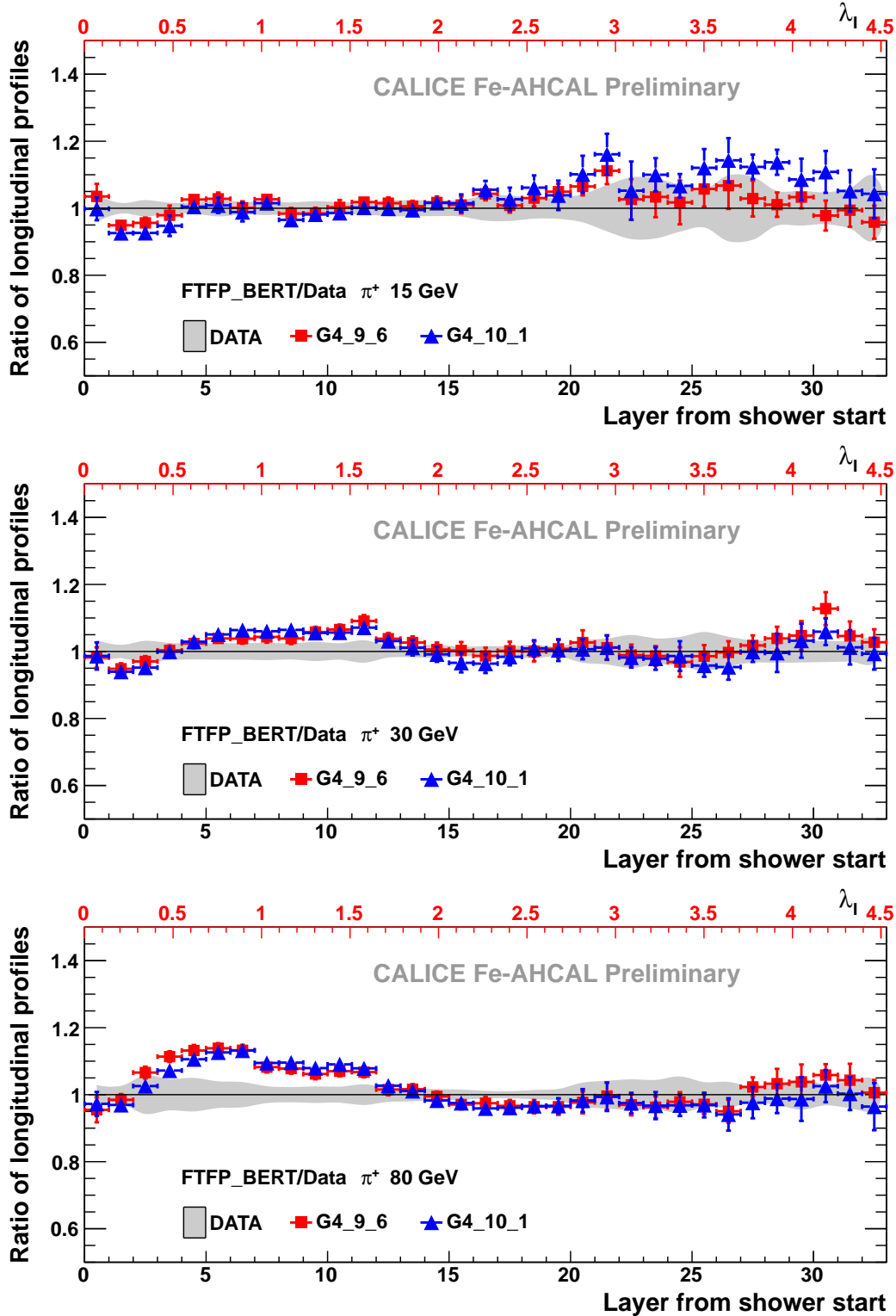


Figure 6: Ratio of longitudinal profiles of showers induced by 15, 30 and 80 GeV pions from simulations with GEANT4 version 9.6 (red squares) and version 10.1 (blue triangles) for FTFP_BERT physics list to those from data samples. The grey band and the error bars show the uncertainty for data and simulations, respectively. The upper red axis show the longitudinal depth in units of λ_I .

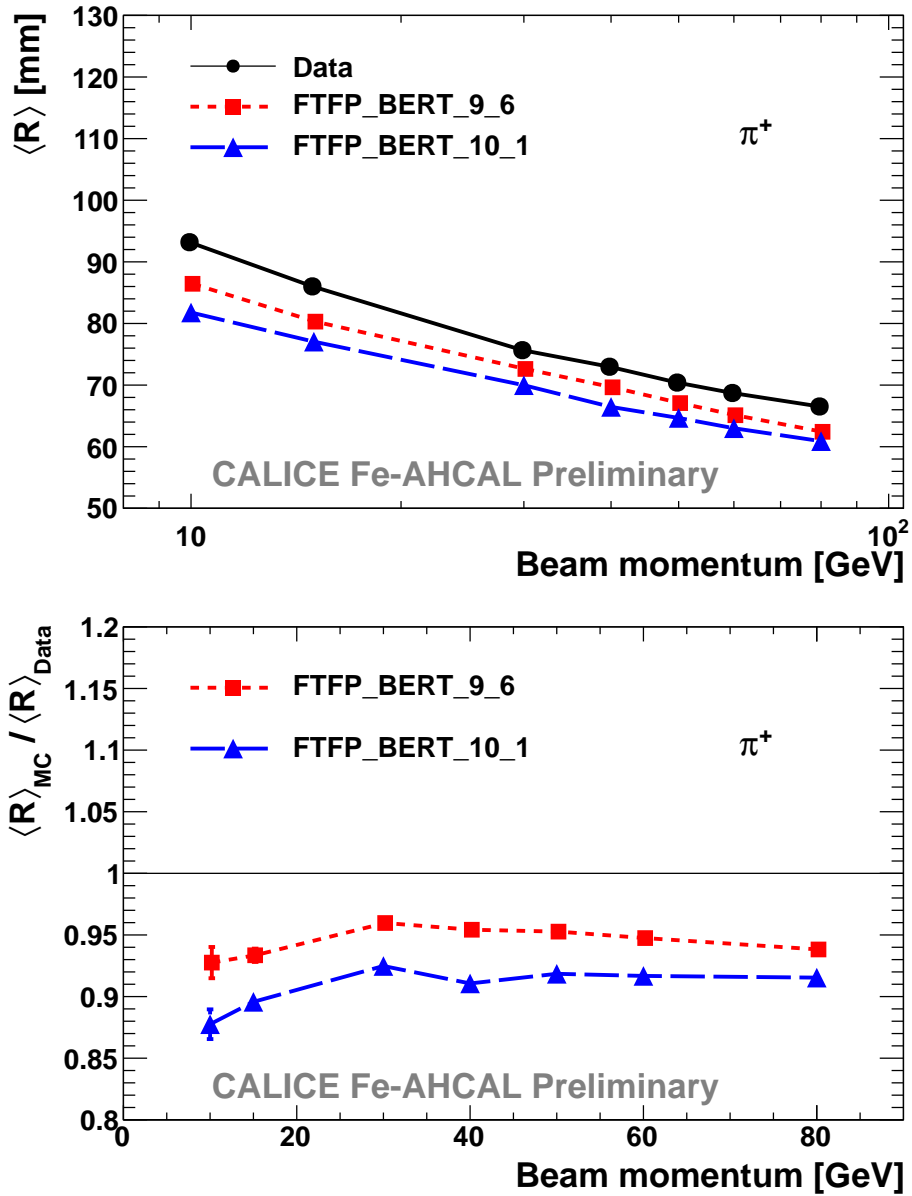


Figure 7: Mean shower radius of pion shower (upper plot) extracted from data (black circles) and simulations with GEANT4 version 9.6 (red squares) and version 10.1 (blue squares) for FTFP_BERT physics list. Ratio of simulations to data is shown in the bottom plot.

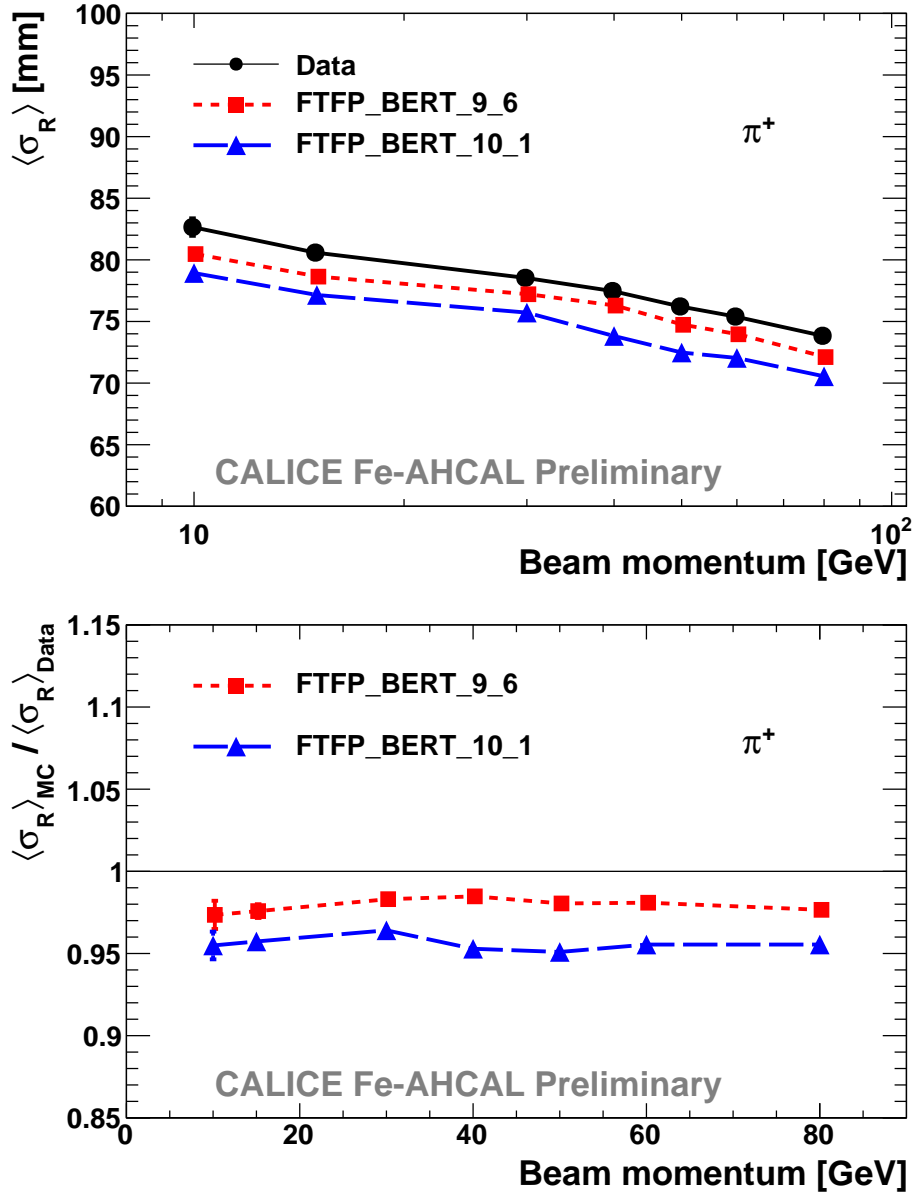


Figure 8: Mean radial dispersion of pion shower (upper plot) extracted from data (black circles) and simulations with GEANT4 version 9.6 (red squares) and version 10.1 (blue triangles) for FTFP_BERT physics list. Ratio of simulations to data is shown in the bottom plot.

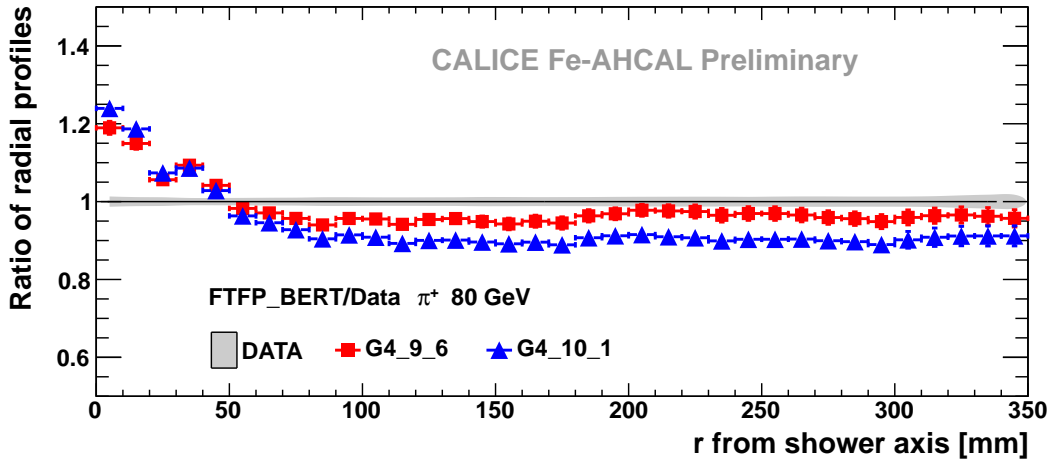
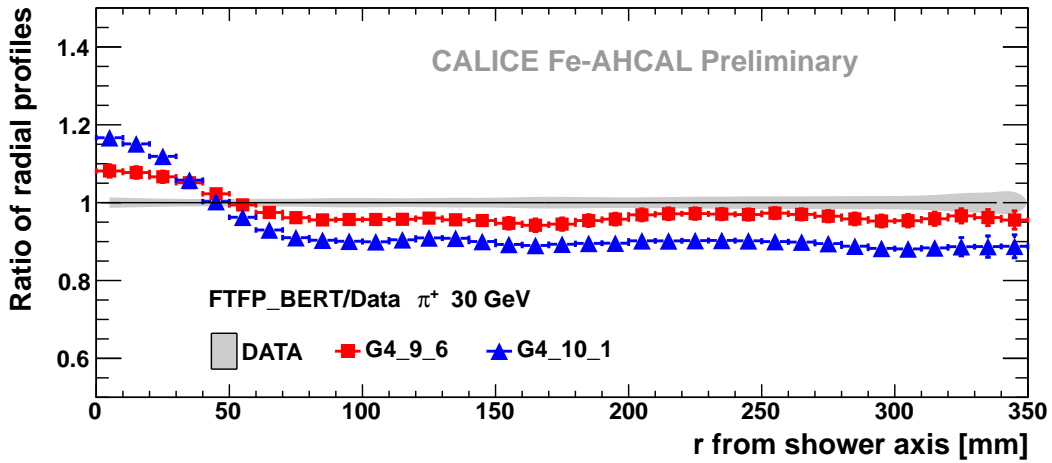
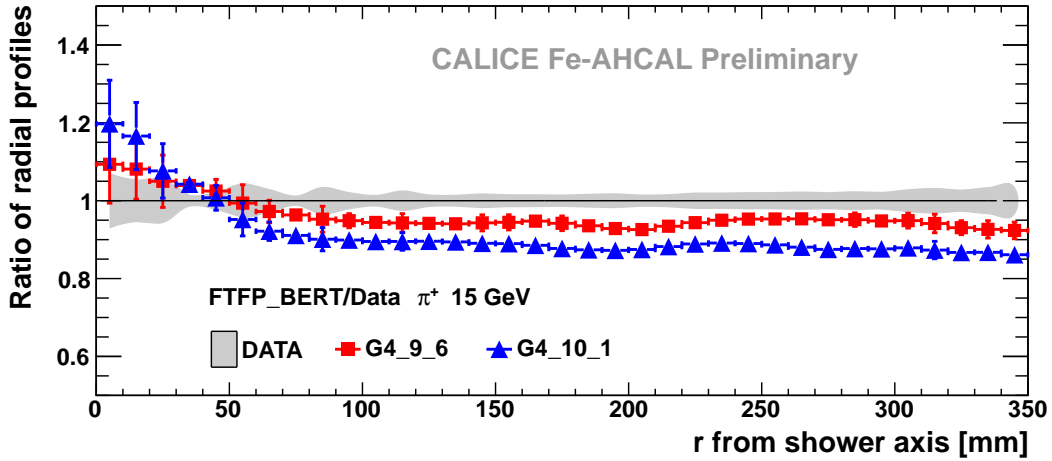


Figure 9: Ratio of radial profiles of showers induced by 15, 30 and 80 GeV pions from simulations with GEANT4 version 9.6 (red squares) and version 10.1 (blue triangles) for FTFP_BERT physics list to those from data samples. The grey band and the error bars show the uncertainty for data and simulations, respectively.